Edition 2022

Ship&Offshore

Special **GreenTech**

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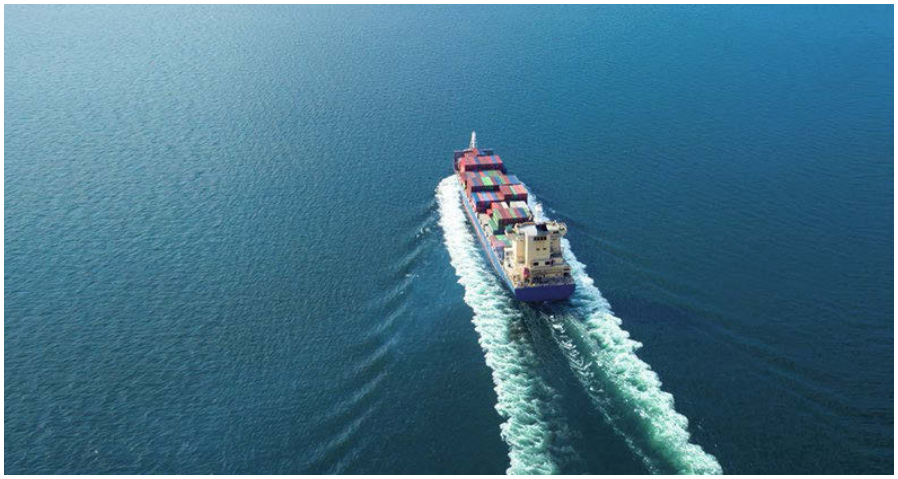

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Need for creative power

It may currently seem as if the world is becoming more and more unhinged – the pandemic is by no means over, there is no end in sight to the Russian war of aggression on Ukraine and Western democracy, and last but not least, the consequences of climate change, which can now no longer be negated, are clearly being felt. It might be time to bury our heads in the sand, some people might think – but that won't get us anywhere.

Quite the contrary – never has the need been greater to display a pioneering spirit and creative power. And the maritime industry continues to demonstrate this.

We present a few of the promising and forward-looking technologies and concepts in this GreenTech Special Edition. This year, six different categories again testify to the breadth of innovation opportunities and relevance of the sector.

The maritime energy transition – the decarbonisation of shipping – plays the leading role throughout. Which propulsion concepts or alternative fuels are most suitable and available for this? Which systems can be operated in a more energy-efficient way? And which are the best and affordable technologies for a sustainable future?

In particular, I would like to draw attention to the article that begins on page 10. Here, for once, the benefits of nuclear power for ship propulsion and floating energy are exclusively highlighted – a controversial topic, not only in the shipping industry. We would be pleased to hear or read your opinion or further thoughts on this. Please get in touch!

New World Maritime Theme highlights environmental legacy

IMO 'MARPOL at 50 – Our commitment goes on' has been selected as the upcoming theme for the International Maritime Organization's (IMO) 2023 World Maritime Theme, which will culminate in a World Maritime Day celebration on September 28th next year. The theme reflects the UN agency's long history of protecting the environment from the impact of shipping via a robust regulatory framework and emphasises its ongoing commitment to this important work.

The IMO's theme 'MARPOL at 50 – Our commitment goes on' spotlights the International Convention for the Prevention of Pollution from Ships (MARPOL), which covers prevention of pollution of the marine environment by ships from operational or accidental causes.

IMO Secretary-General Kitack Lim said: "A lot has changed in shipping in the 50 years since the MARPOL Convention was adopted on November 2nd 1973, and IMO's commitment to protecting and preserving the marine environment has remained unwavering. The World Maritime Theme for 2023 will allow us to celebrate this legacy, while also underscoring our dedication to building on the existing foundations as we move towards a brighter future together.

"Our work to reduce greenhouse gas emissions is critical, and – given the urgency of the climate crisis – we must act now to strengthen our ambitions on this matter. We must also tackle other issues including protecting biodiversity, biofouling, the transfer of invasive species, and plastic and noise pollution. Protecting the marine environment requires shared action and I look forward to what the next 50 years will bring," he added.

The theme, which promotes discussions on the next phase of IMO's work to further protect the planet and the oceans, is also linked to the UN 2030 Agenda for Sustainable Development and the 17 Sustainable Development Goals (SDGs). These include affordable and clean energy (SDG 7); industry, innovation and infrastructure (SDG 9); climate action and sustainable use of the oceans, seas and marine resources (SDGs 13 and 14); and the importance of partnerships and implementation to achieve these goals (SDG 17).

The IMO Council, meeting for its 127th session, endorsed the theme following a proposal by IMO Secretary-General, Kitack Lim.

History of the Convention

The *Torrey Canyon* oil spill in 1967, the largest oil disaster at the time, was one of the key moments that led to the develop-

ment of the MARPOL Convention. The 1970s saw increased global awareness of the need to protect the marine environment from all sources of pollution, subsequently resulting in the adoption of the MARPOL Convention and the 1978 MARPOL Protocol in 1973 and 1978, respectively. The combined instrument entered into force on October 2nd, 1983.

MARPOL 73/78 is the most important international instrument covering prevention of pollution of the marine environment by ships from operational or accidental causes. In 1997, a Protocol addressing prevention of air pollution from ships was adopted and entered into force on May 19th, 2005.

Evolution of MARPOL

Today, MARPOL covers pollution of the sea by oil, noxious liquid substances in bulk, harmful substances in packaged form, sewage and garbage from ships, air pollution from ships, and regulation of energy efficiency. It also allows for the adoption of special areas with even stricter controls on operational discharges.

The Convention has evolved through the years. Some highlights include the requirements for oil/water separators on ships, phasing out of single-hulled oil tankers in 2010, the establishment of several special areas including the Antarctic area, the introduction of the mandatory IMO Member State Audit Scheme (IMSAS) in all MARPOL annexes, the introduction of the IMO 2020 global sulphur limit, and the adoption of technical and operational measures to enhance the energy efficiency of ships.

The adoption of the Initial IMO Greenhouse Gas (GHG) Strategy in 2018 to decarbonise the sector as soon as possible before the end of this century has set the policy framework for the development and adoption of further measures within MARPOL to enhance energy efficiency of ships

Revision of Initial GHG strategy.

In its recent session, the MEPC reiterated its commitment to review and strengthen the IMO Initial Strategy on the reduction of GHG emissions from shipping, with a view to adopting a revised strategy in mid-2023. The MEPC 78 session (June 6th to 10th) made further progress with the discussions towards the revision of the Initial GHG Strategy, as initiated during the last session (MEPC 77). The revision will take into account the commitment to strengthen the levels of ambition of the Initial Strategy and the needs of developing states, in particular small island developing states and least developed countries.

Two anchor handlers committed for another year to The Ocean Cleanup

Maersk Tender and *Maersk Trader*, the two Maersk Supply Service anchor-handling vessels currently supporting The Ocean Cleanup in the Pacific Ocean, have been contracted for an additional year of operations Source: MSS

FLOATING PLASTIC | Maersk Supply Service (MSS) has assigned the two anchor-handling offshore vessels, *Maersk Tender* and *Maersk Trader* for another year of support for The Ocean Cleanup, a Dutch non-profit green technology organisation. The vessels will continue to be deployed supporting the collection of plastic waste in the Great Pacific Garbage Patch, the world's single largest accumulation of ocean plastic.

The two MSS vessels have been supporting The Ocean Cleanup's campaign to optimise its plastic-harvesting processes by ensuring their viability and capacity for scale-ups in future. MSS has provided offshore expertise and safety procedures for the project which extends over large areas of remote ocean. It has also given logistics support including the transport of project equipment and so-called 'Interceptor' systems to prevent plastic from entering the ocean from rivers.

The Great Pacific Garbage Patch, also known as the Pacific trash vortex, extends from the west coast of North America to Japan. It comprises two areas – the Western Garbage Patch near Japan, and the Eastern Garbage Patch between Hawaii and California.

In May last year, MSS committed a second vessel and crew to support trials of The Ocean Cleanup's System 002. By October, the two vessels returned to shore having completed tests successfully. The trials demonstrated that The Ocean Cleanup's System 002 could safely, efficiently, repetitively, and reliably remove plastic from the ocean, MSS said. System 002 is now continuing to collect plastic across the area of sea while System 003, a larger unit, is being developed ashore. This latest version is likely to provide a blueprint for subsequent scale-ups.

Explaining MSS's continuing commitment to the project, Jonas Munch Agerskov, chief commercial officer, said: "Ocean health is integral to Maersk Supply Service's core values and strategy. The oceans hold the key to many of the energy challenges ahead of us and so we believe we have a responsibility to protect and restore ocean health. It is important that we proactively use our marine capabilities to improve ocean health through partnerships and policies, and so we are very pleased to be able to continue our collaboration with The Ocean Cleanup."

So far, the Dutch organisation has collected about 67,000 kg of plastic waste from the ocean area.

Norway supports 'green corridor' development in Europe

SEASHUTTLE | A project between partners Samskip and Ocean Infinity to create one of Europe's first 'green corridors' on a route between Oslo Fjord and Rotterdam has received a grant of NOK 150 million from Norwegian state enterprise, Enova. Rotterdam-based Samskip and Ocean Infinity of Houston plan to design and build two hydrogen-powered, remotely controlled, and autonomous-ready, container ships for the route by 2025.

The SeaShuttle project, originally announced earlier this year at Nor-Shipping, will involve the development of two container ships, each powered by a 3.2-MW hydrogen fuel cell. The funding from Enova, part of Norway's Ministry of Climate and Environment, is important because it will allow the partners to move ahead on contracting two 500-TEU vessels with main propulsion arrangements that can be adapted to run on hydrogen fuel when it becomes available. A diesel-electric engine will also be installed on board and will ultimately provide a back-up source of power.

Samskip Norway CEO, Are Gråthen, does not foresee a holdup in hydrogen fuel availability in Norway. "We have faith that green hydrogen will be affordable and available in Norway," he declared.

Commenting on the SeaShuttle project, Gråthen said the initiative is part of the company's 'making green logistics easy' strategy. "Securing this funding provides a platform to make emissions-free container shipping a reality," he said. "Together, Samskip and Ocean Infinity will also accelerate their plans to advance autonomous ship technologies, and remote operation of ships and cargo handling equipment. These ships are the first part of an exciting collaboration with Ocean Infinity."

The Houston company's CCO, Christoffer Jorgenvag, commented: "Ocean Infinity's enabling technologies can facilitate green corridors but also the broader decarbonisation and transformation of maritime operations. The emphasis today is on the SeaShuttle vessels, which are just part of Ocean Infinity's overall strategy of unlocking innovation to deliver truly sustainable maritime operations. We would like to thank Enova for their support for our vision which represents a firm endorsement of our ground-breaking approach and allows us to proceed at full speed in bringing this project to life."

The Silk Alliance to develop Asian Green Corridor Cluster

FUEL TRANSITION | Lloyd's Register Maritime Decarbonisation Hub has been instrumental in bringing together a diverse group of eleven other partners to establish 'The Silk Alliance'. The members, who include five owners, a ship manager, a shipyard, a bunker supplier, an engine manufacturer and two financial institutions, aim to develop a fleet-specific fuel transition strategy for container ships operating in Singapore and elsewhere in Asia.

The initial members are MSC Shipmanagement Ltd, Pacific International Lines (Pte) Ltd, Wan Hai Lines, X-Press Feeders, Yang Ming Marine Transport Corp, Keppel Offshore & Marine Ltd, Singfar International, Wärtsilä, Asian Development Bank, and ING.

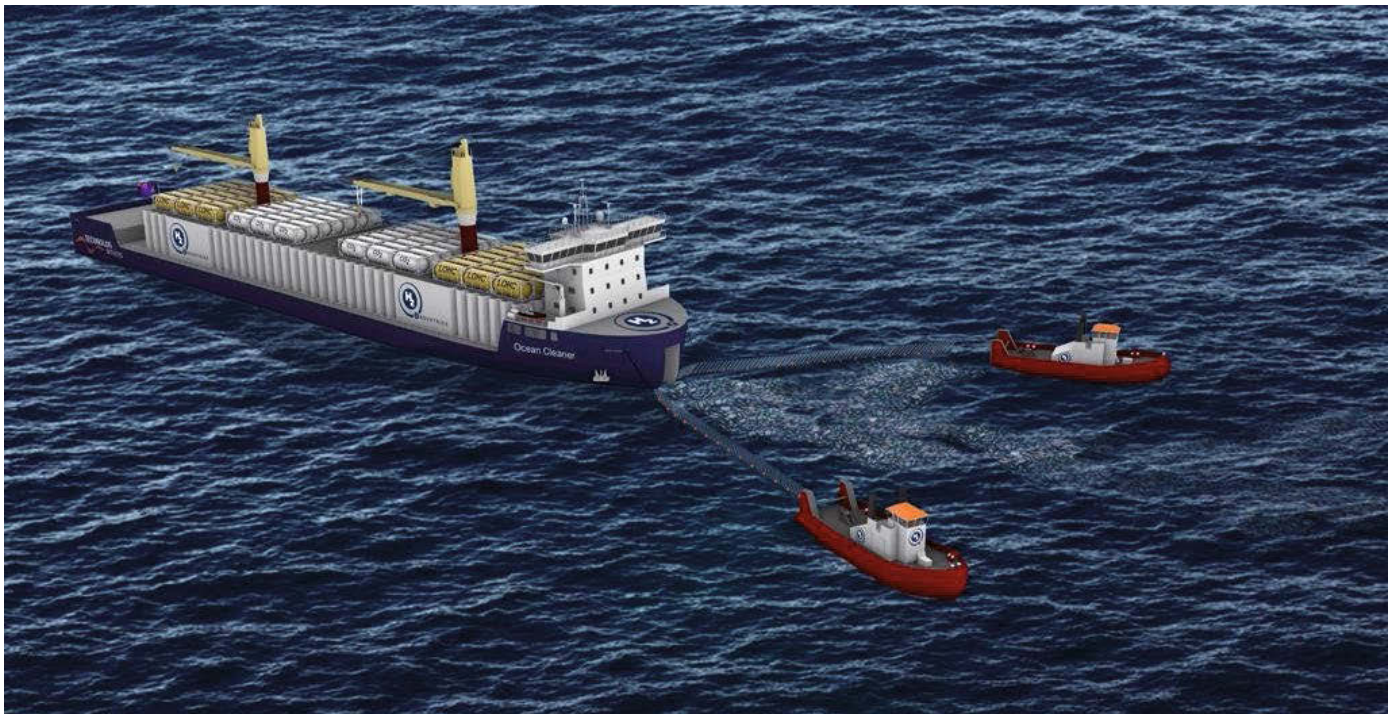
The resulting Green Corridor Cluster will help to generate more collaboration across shipping as the sector squares up to meet its COP26 commitments. One key move is to identify moves that may help to lower the investment risk that is obstructing the wider uptake of sustainable carbon-neutral fuels.

Initially, the Silk Alliance Members hope to attract more stakeholders such as fuel providers, port operators and governments to support the Green Corridor Cluster. They will also draw on their own areas of expertise to contribute to a fleet-specific fuel transition strategy for container ships operating primarily in Asia. The initiative will be based on the Lloyd's Register Maritime Decarbonisation Hub's First Mover Framework, the partners said in a statement.

Charles Haskell, Lloyd's Register's Decarbonisation Programme Manager, said: "This is a first-of-its-kind in developing fleet transition strategies for multiple stakeholders, not just with the support of major players within the maritime industry, but also with operators in other industries that serve the maritime supply network – the shipowners, shipyard managers, financial institutions, bunker suppliers, and engine manufacturers.

He continued: "The Silk Alliance aims to establish a fleet-specific decarbonisation strategy and green corridor implementation plan that encompasses key links in the maritime supply network which are critical to providing maritime players of all sizes with the resources to transition to carbon-neutral fuels and vessels."

‘Beyond green’ process to collect plastic waste and make hydrogen



The ship will travel at four knots with the waste plastic collected by two smaller vessels towing a two-mile net that funnels the waste from the surface to a depth of 10m

Source: H2-Industries/Technolog

CONCEPT SHIP | New York-based H2-Industries, an energy storage specialist, and naval architecture company, Technolog Services of Hamburg, are to collaborate on drawing up 3D designs for a ship to collect plastic waste from the sea, convert it into clean hydrogen, and enable any surplus to be shipped ashore. This combination of gathering plastic waste at sea and using it to produce sustainable hydrogen has been described as ‘beyond green’ or ‘greener than green’.

The ship, likely to be more than 150m long, will travel at four knots with two smaller vessels towing a two-mile net that collects waste from the surface of the sea down to a depth of 10m. An open-bow design will enable the plastic waste to be fed onto conveyors and into the ship’s storage hold. The waste will then be converted into hydrogen using H2-Industries thermolysis process, developed for hydrogen production facilities ashore.

For every 600 kg of waste, about 100 kg of hydrogen can be produced, the company said. This is then ‘stored’ in a liquid organic hydrogen carrier (LOHC), a fluid that can carry hydrogen in 20-foot containers. These will be transferred to smaller vessel for shipment to shore.

The partners envisage that the ship will operate on electric motors using LOHC as fuel and creating electricity using H2-Industries 19-inch eRelease racks. Many of these will be used to provide the approximately 2 MW of power likely to be required by the ship. The New York company has already developed this technology for possible applications aboard cruise ships, large container ships and big tankers.

H2-Industries has received preliminary approval for its first LOHC hub in East Port Said, Egypt. The company said that it is also discussing similar facilities with more than 20 countries, as well as several ports.

The LOHC carrier fluids bind hydrogen chemically into a state in which it is neither volatile nor capable of self-discharging. It can only be hydrogen-charged or discharged by using a certain catalyst in a process that can be undertaken as many times as necessary, making it remarkably cost-effective, H2-Industries explained. The charging (hydrogenation) and discharging (dehydrogenation) are independent processes using proprietary catalyst technology.

The company said that a constraining factor is the volume of plastic feedstock. One rotary kiln can handle 600 kg of waste every hour, generating about 100 kg of hydrogen. Ships will be designed with a number of kilns to match the speed of plastic collection, and it is thought that each ship will remain in one location for about a year before moving on to another waste site. The vessel will be equipped with technology used in the sea water intakes at desalination plants to ensure the protection of wildlife and habitats.

H2-Industries’ CEO, Michael Stusch, said: “It is becoming increasingly clear that the shipping industry can make a positive impact on reducing global emissions. At H2-Industries, the plan is to help decarbonise industry and power generation, while cleaning up our water resources and converting pollutants into an energy source. To achieve this, we are looking for investors. Once the investment is in place, we expect each ship will be built within roughly 24 months.”

Low- and zero-emission handymax designs unveiled

The Aquarius Eco Handymax II bulker design is all electric and is equipped with fuel cells
Source: Eco Marine Power

AQUARIUS ECO HANDYMAX | Fukuoka-based energy technology company, Eco Marine Power, has released details of two handymax bulker designs incorporating a range of power technologies to ensure low or zero emissions. The company's design concept, Aquarius Eco Handymax, is based on a hybrid setup incorporating a combination of sustainable sources of power, energy-saving devices, and a low-emission engine. A more advanced design, Aquarius Eco Handymax II, is all-electric and also has fuel cells.

Both designs will incorporate the company's integrated sail-assisted propulsion and solar power system, Aquarius Marine Renewable Energy (Aquarius MRE®). ClassNK granted Approval in Principle for this last year and the company has applied for a further patent relating to this system, it said in a statement.

Some of the technologies that will be applied to the zero-emission design are to be installed on an operating handymax bulk carrier this year. Their performance will be evaluated in cooperation with the shipowner and other strategic partners. The technologies include:

- Aquarius MRE, EnergySail® array, and Aquarius Marine Solar Power
- Propeller hubs or caps
- Air lubrication system
- Aquarius Management & Automation System
- DC mini-grids and energy storage
- Variable speed electric drives
- Electric propulsion
- Fuel cells
- Energy-saving device package

Eco Marine Power's chief technology officer, Greg Atkinson, commented: "The Aquarius Eco Handymax is the result of years of research and development including shore-based and ship-based trials. The design focus in not based on any one solution or technology however, but rather how various alternative power sources and energy-saving devices can work together to achieve the zero-emissions operation of a large ship."

Several companies are collaborating on research and development relating to the Aquarius Eco Handymax II project through the virtual Eco Marine Power Research Institute. More companies are expected to join in the months ahead.

Illustration of *Ulstein Thor* and *Ulstein Sif* with an autonomous surface vehicle underway

Source: Ulstein

Nuclear power offers shipping a carbon-free option

ENERGY SECURITY As the world energy crisis deepens and energy security becomes the top priority for many countries, all power options must be on the table, say experts. They point to small nuclear power plants on ships and floating facilities which could provide a carbon-free option at dramatic scale. The technology is well tried and tested and available today, writes freelance journalist Paul Bartlett.

Nuclear power has consistently been ruled out for commercial shipping on the grounds of safety and cost. This, according to some experts, is based on an outdated misconception that all nuclear technology is inherently unsafe. In the minds of many people, the fallout from incidents such as Three Mile Island, Chernobyl and Fukushima lingers on.

However, many now believe that these opinions are misplaced. As an energy source, the nuclear industry has an unparalleled safety record and, together with renewables, is far safer than any fossil-based source of power. Unfortunately, experts say, past nuclear disasters have overshadowed the entire sector. They have obscured a range of nuclear technologies that have been developed over decades and are inherently safe, extremely powerful, well tried and tested, and entirely carbon-free.

Even before the pandemic, world energy supplies were close to tipping point. Russia's war has now transformed a challenge into a crisis for many countries. In fact, the issue of energy security is now so serious that some coal-fired and nuclear power plants in Europe have had decommissioning decisions reversed and are now due for life extensions and continued operation.

Nuclear power is not new in shipping. Navies, including those of the United States and the UK, have opted for nuclear power as the energy of choice for some vessel types. Perhaps surprisingly for those who believe nuclear energy to be dangerous, these vessels have an impeccable safety record. Russia, meanwhile, has a fleet of nuclear icebreakers to keep northern sea routes open, and although safety statistics are not available, these are also believed to have a first-class safety record.

However, the nuclear power that has been used in these sectors is generated from high-pressure reactors that would not be suitable in a commercial shipping context.

But there are others that are. And experts claim that there is scope to generate cheaper power from these energy plants and on a far greater scale than from renewables.

European initiatives

In April, privately owned Norwegian ship designer and builder, Ulstein, introduced a new concept in expedition cruising based on nuclear-generated electricity supplied to electric expedition cruise vessels in remote areas. Launched at Seatrade Cruise Global in Miami, the Ulstein concept is based on one 149m-long floating power plant, *Ulstein Thor*, using thorium-based molten salt reactor (TMSR) technology to provide electricity for the sustainable operation of four electric cruise ships, *Ulstein SIF*s.

Torill Muren is lead naval architect at Ulstein Design & Solutions. "*Thor* essentially operates as a floating, mobile, multi-purpose power station", she explained, "one that never needs refuelling – instantly creating the ocean infrastructure needed to facilitate a new battery revolution. In *Thor*'s case, it would offer the charging capacity to satisfy the power needs to four expedition cruise ships … We see it as the missing piece of the puzzle when it comes to enabling safe, sustainable operations, anywhere on earth. As such, it really does have the capability to transform our industry."

Commenting on the Ulstein concept, nuclear expert and TMSR specialist, Professor Jan Emblemsvåg of the Norwegian University of Science and Technology (NTNU) and a specialist in thorium and nuclear power generation, said: "I see this as the most viable, and potentially the only credible solution, for a zero-emission fleet that can operate under commercial terms and cost levels. The Thor concept is exactly the kind of innovation we need for sustainable success at sea."

Emblemsvåg and the NTNU team have recently been awarded a NOK 10 million grant from the Norwegian Research Council for more research into nuclear power for shipping. The university is also at the forefront of research into many new energy technologies, notably hydrogen, which can be produced in its green form in Norway thanks to easy and abundant access to renewable electricity. In most other countries, the production of hydrogen is carbon-intensive and will require carbon capture and storage technology as an add-on.

TMSR technology, which is more than six decades old, is inherently safe because it is an unpressurised system that is fuelled by a liquid (in this case, thorium) and therefore cannot melt down. And these small power plants can be designed not only as floating units such as the *Ulstein Thor* to provide power for other electric vessels, but also to provide a permanent floating source of power generation.

Copenhagen-based Seaborg was awarded a European Innovation Council Accelerator grant to support development of its turnkey floating nuclear power plant based on uranium MSR technology
Source: Seaborg

They could feed into electricity grids on land or be provided as dedicated power plants for energy-intensive sectors on land or sea. London-based Core Power, for example, has recently unveiled a plan to use nuclear power to make green ammonia for a green corridor across the Atlantic. Depending on power plant design, these nuclear facilities can be built to operate without refuelling for years, even decades.

Earlier this year, Copenhagen-based Seaborg was awarded a European Innovation Council (EIC) Accelerator grant to support development of its turnkey floating nuclear power plant based on uranium MSR technology. The plant can be moored conveniently to feed into an electricity grid ashore, or to be located adjacent to a green hydrogen or ammonia production facility.

Until recently, the cost of nuclear power was an issue, according to shipping economist Dr Martin Stopford. When MSR technology first became available around the middle of the last century, oil was extremely cheap. Stopford's analysis has shown that oil bunkers cost an average of about USD 11.90 per tonne between 1962 and 1970.

Changing economics

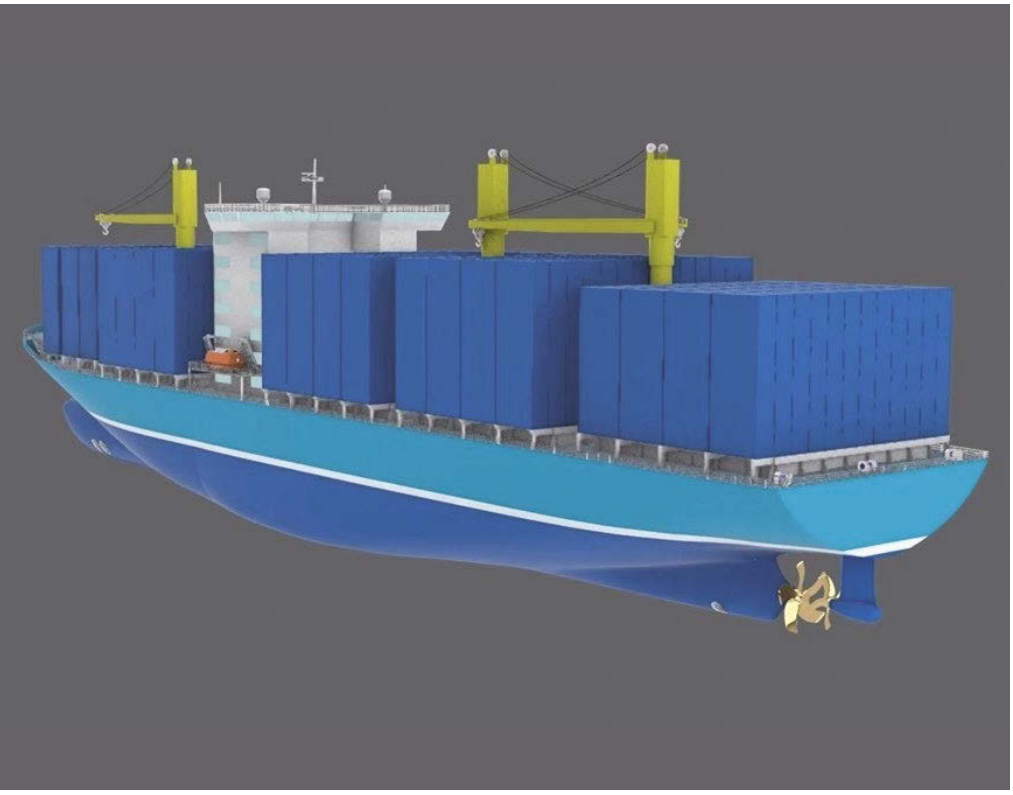
"When shipowners like Onassis borrowed to purchase supertankers, oil was the only option," Dr Stopford said recently. "Nuclear propulsion required much more up-front capital and would hardly have endeared them to their customers, the oil companies!"

But the backdrop has changed dramatically. "Climate change regulations are now phasing out cheap fossil fuels," he added. "The alternative green fuels will be much more expensive and shipping companies will have to compete with electrical generation, chemicals, and other land-based industries for the scarce supply of green hydrogen, ammonia, and methanol. So nuclear propulsion is quietly creeping back onto the agenda."

He noted key benefits of nuclear fuel for ships. Perhaps the most important of these is the fact that using nuclear fuel does not require frequent bunkering or the global bunkering infrastructure which, by some estimates, is likely to require billions of dollars to build. Ships would also be significantly more productive, with much smaller machinery spaces and no requirement for bunker tanks – therefore more revenue-generating potential.

But Stopford conceded that it will be a steep hill to climb. Proponents of MSRs claim this technology is much less vulnerable to explosion than the pressurised reactors used on land, he noted. But regrettably, anti-nuclear sentiment is not technology-specific.

"So with the right ship, the right company, the right charterers, the ›



Artist's impression of Core Power's proposed facility for a ship-based floating desalination plant
Source: Core Power

right bankers, and the right technology, nuclear propulsion should be back on the agenda for power-hungry, deep-sea ships," he said. "But ultimately it is not just economics. Even with MSR reactors, nuclear propulsion is not risk-free. So not much can happen until bankers, insurance companies, and the public get comfortable with the risk."

Scale of challenge

Professor Emblemsvåg, who previously held positions at marine engineering firm Rolls-Royce, and shipbuilder Vard, both in Norway, has researched the volumes of energy required for shipping's decarbonisation process – in other words, the energy required to provide enough sustainable power for sectors of the world's commercial fleet.

Emblemsvåg's findings are unsettling. Using the large container ship sector as a reference, he analysed the power requirements of 580 container ships of more than 10,000 TEU operating on the world's largest trade lane between Asia and Europe. Specifically, he used the voyage between Shanghai and Amsterdam for his calculations.

He compared the volume of heavy fuel oil (HFO) required with the volume of ammonia needed for the same voyage. Such a vessel, he concluded, would need 8,400 tonnes of HFO or 18,100 tonnes of ammonia for the voyage because of the latter's lower energy density or thermal value.

If the ammonia were green on a well-to-wake basis – in other words, it was made from green hydrogen through hydrolysis – Emblemsvåg estimated that 9-15 MWh of energy would be required to produce every tonne of ammonia. He also calculated that a ship requires about 190 GWh of energy per one-way voyage. Assuming it is at sea for 80% of the time and completes twelve such trips each year, it would require 2.2 TWh of energy over a year, equivalent to almost 500,000 British households, he said.

In 2020, the UK generated 75.6 TWh of electricity from the wind, both on- and offshore. So, the UK's entire wind energy from that year would have been sufficient to provide green ammonia for about 30 large container ships.

Emblemsvåg said that his calculations, which obviously go into much more detail, use only the large container sector deployed on one route as an example. The same issues apply to other shipping markets and, more generally, to decarbonising primary energy sources in any country. Except, at a national level, the process is even more demanding.

"Hence, the green transition is all about scale," he wrote in a recent paper, "and scale cannot be delivered in any other credible way than through nuclear energy … The simple fact is that natural uranium contains three million times more energy than coal, and thorium container 3.5 million times more … If we are to achieve a green transition, then the first we must do is to kill several myths concerning nuclear energy, and we must be willing to discuss measures at a relevant scale compared to the challenge."

A classification view

Mark Tipping is Power to X Director at Lloyd's Register (LR). In a paper earlier this year, he described how MSRs and heat pipe reactors (for smaller applications) can be used to provide energy for turbines to generate electricity. He noted several companies active in the nuclear space – Core Power (ships and offshore), Seaborg (floating power generation), and Prodigy Clean Energy (floating power generation).

He listed a range of applications for ships and floating assets. They included liner routes between defined ports, large vessels such as container ships where the extra space required for green fuels would affect their economics, and ships operating within single-state waters. There is also significant potential for floating nuclear power to provide energy for hydrogen ammonia production plants and dedicated electricity generating facilities, he noted.

Tipping also clarified today's statutory requirements for nuclear ships and noted that an update for SOLAS Chapter VIII is required and proposals will hopefully be presented in 2024-5. However, LR aims to have a high-level set of rules applying to offshore and shipping initiatives by the second quarter of 2023.

Other classification societies, such as DNV, do not see nuclear power for shipping high on the agenda in the foreseeable future. According to a recent statement made during Posidonia in Athens, it may take a decade to develop a suitable regulatory framework and deal with high capex cost and safety concerns.

What is your opinion on nuclear power as a carbon-free option for shipping?
Please send your feedback, comments or questions to our editor in chief,
Kathrin Lau
(kathrin.lau@dvvmedia.com).

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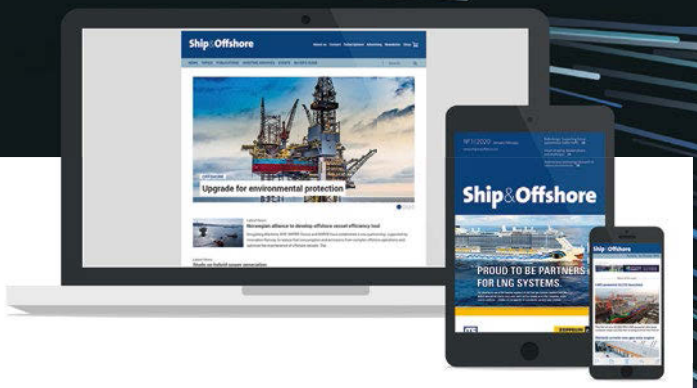

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Third generation with major enhancements

BATTERIES | The new Navius MRS-3™, a third generation of marine batteries from Leclanché, is said to offer a range of improvements over the earlier MRS-2 range. The latest type of Marine Rack System (MRS) batteries will offer 27% more power for the same footprint, and liquid cooling which extends battery life, saves space, and enables a 50% hike in energy density, the Swiss company said in a statement. The batteries will also have a smaller carbon footprint with cells, modules, battery management systems, and racks all manufactured in the European Union.

Due to be launched at the Electric & Hybrid Marine World Expo in Amsterdam in September, the MRS-3 range has already attracted its first customers. It has been specified in several vessel designs including Scandlines' 10-MWh PR24 zero-emission freight ferry.

Leclanché said that the MRS-3 family will provide more options for ship designers and builders as they develop new electric and hybrid vessels. The third generation not only offers improved power performance, but also benefits from increased modularity and greater safety, the company claimed. Safety has been a key consideration in the design of the latest range, from individual battery cells to the overall system. Features include:

- Laminated ceramic battery separators to protect against short circuits and the new electrolyte design minimises the potential volume of flammable gases;
- Slave units in each module to measure cell voltages, temperatures, and run diagnostics;
- IP-rated enclosures to protect against mechanical and electrical incidents and prevent the ingress of water and contaminants in or out;
- Battery Management System with slave units inside every module together with an option for a remote monitoring system;
- Liquid cooling for greater longevity and up to 50% higher energy density;
- A fail-safe automated system in each module enclosure to prevent thermal propagation.

The Navius MRS-3 racks, with seven different heights, can fit into almost all battery spaces, the company said. And with a reduced rack width, a third less front access is required for maintenance. Cooling pipes are positioned on the front of the racks and high voltage cables with a 'quick-connect' system are also accessible at the front.

The company is offering three different service plans. A reactive service option includes a 24/7 hotline for remote support and access to in-house field engineers and Leclanché's partner network. A preventative service package includes maintenance training, troubleshooting, and an annual preventative maintenance check on board to carry out visual, mechanical and electrical routine checks. A predictive service arrangement is based on secure data monitoring of the battery systems. Users can access an IoT platform enabling them to see analysis and reports on the battery system condition. They also receive analysis, warnings, and recommendations over the lifetime of their systems.

Leclanché CEO, Anil Srivastava, said: "Leclanché's new Navius MRS-3 represents the latest generation in powerful, safe and emission-free electrification systems for the maritime industry. We've poured everything we've learned from our award-winning MRS-2 system into this project, setting a new performance standard for marine vessels including its liquid-cooling architecture which is now universally recognised as the safest in the industry."

Power integration and sustainability advisory service

X-EL ENERGY SOLUTIONS | WinGD has introduced a new battery-hybrid power integration and sustainability advisory service, X-EL Energy Solutions. By integrating two-stroke marine engine control into the electrified vessel power system, X-EL Energy Solutions will widen the range of vessels that can potentially benefit from electrification, the company explained.

The two-stroke engine, which offers higher efficiency and lower running costs than auxiliaries when generating electricity, is central to a marine power system. But main engines are increasingly part of more complex energy systems in which different sources of power must function efficiently together. The new advisory service can therefore support ship designers, builders, energy integrators, owners and operators as they seek to maximise the efficiency of more diverse marine energy arrangements. The system uses digital tools to simulate, design and deploy the entire vessel power-train, incorporating in-line shaft generators, frequency converters, thrusters and, when required, battery systems, integrated with the main engine. An energy management system controls the entire setup and provides scope for dynamic optimisation of real-time ship operation.

This ensures that the vessel always has the right power delivered in the most fuel-efficient way. A combination of simulation and real-time monitoring identifies the most suitable mode of operation for the prevailing conditions, while also improving reliability and load response across the integrated power system.

WinGD's close relationships with suppliers of other sources of shipboard energy, including shaft generators, frequency converters, and batteries, has facilitated the accurate simulation of energy systems. This, the company explained, has ensured that an optimal system can be developed virtually, reducing the risk of integration challenges when ships are being commissioned or, later, in service.

Stefan Goranov, general manager, Sustainability Solutions at WinGD, commented: "Electrification will be crucial to reduce emissions and to reduce consumption of expensive fuels. Our holistic approach to designing power arrangements involves the entire energy system, not merely the main engine or any other individual component or sub-system. The X-EL solutions are in complete alignment with the maritime industry's ongoing energy transition by enabling greater efficiency."

The introduction of the X-EL Energy Solutions follows the company's first contract to provide hybrid system integration and energy management for four LNG-fuelled pure car and truck carriers due to enter service in 2023. The ships will be powered by X-DF2.1 dual-fuel engines as part of a battery-hybrid system developed by X-EL Energy Solutions.

Newcastlemax bulk carrier to have WindWings installation

SAIL POWER | Singapore-based Berge Bulk is to install four BAR Tech WindWings by Yara Marine Technologies on board its 210,00dwt Newcastlemax bulk carrier, *Berge Olympus*, in the second quarter of 2023. The 50m-high solid wing sails could reduce carbon emissions by as much as 30% through a combination of wind propulsion and route optimisation, Berge Bulk said. The move represents an important step in the company's aim to be carbon-neutral by 2025 at the latest, and to have a zero-carbon oceangoing bulk carrier in operation by 2030.

BAR Tehnologies received an Approval in Principle (AiP) from DNV for BAR Tech WindWings by Yara Marine Technologies in November 2021. The AiP provides assurance to owners and operators that the technology has been comprehensively assessed in terms of practicality and safety, and its applicability to sea-going vessels. The AiP also covered the deployment and functionality of WindWings in operation, use in extreme weather conditions, and system redundancy.

James Marshall, Berge Bulk CEO, said: "This partnership with BAR Tech and Yara Marine is a great step towards our transition to zero-emissions operations … At Berge Bulk, we believe in the results that can be achieved by harnessing wind power. Evaluating this groundbreaking technology, the estimated impact on reducing emissions can be at least as significant as transitional fuels. We look forward to continuing our collaboration with Bar Tech and Yara Marine to install the first WindWings on board *Berge Olympus* and for the optimisation needed when deploying such innovate technologies."

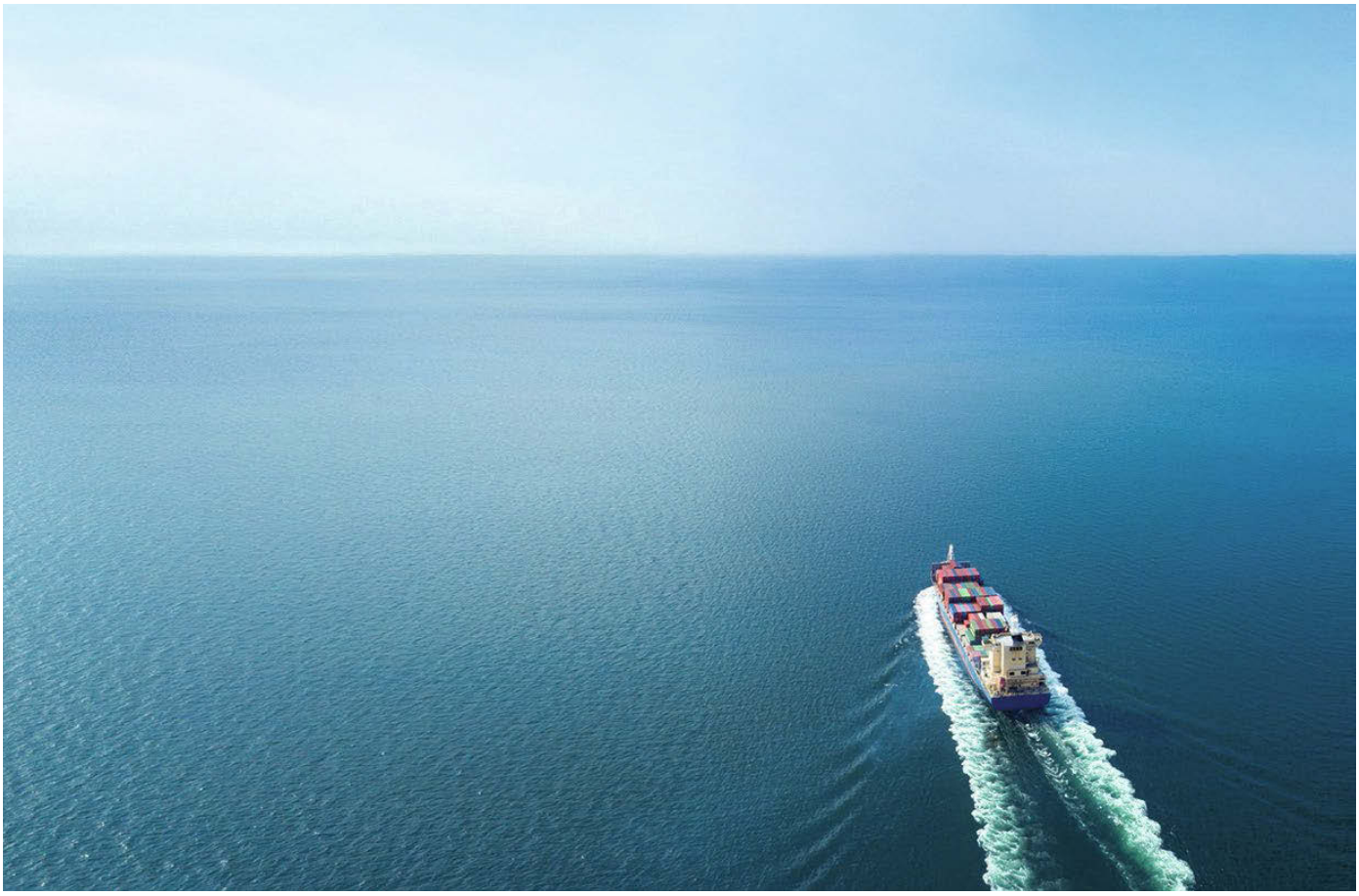
Speaking on behalf of Yara Marine Technologies, CEO Thomas Koniordos stressed the need for an inclusive approach. "I strongly believe that many valuable solutions deserve greater attention," he said, "and wind-assisted propulsion is one of them. This collaboration between Berge Bulk, BAR Technologies, and Yara Marine skyrockets the momentum for wind propulsion."

BAR Technologies' CEO, John Cooper, commented; "By retrofitting WindWings technology to existing vessels, firms like Berge Bulk can begin to make an immediate impact on decarbonising their fleets while at the same time seeing significant efficiencies in current fuel use. With Berge Bulk joining a pipeline of WindWings installations through 2023, we look forward to working with our partners to make significant inroads into reducing vessel carbon emissions."

Berge Bulk's latest initiative followed soon after an announcement at Posidonia that the company was to collaborate with Kongsberg Maritime on the deployment of decarbonisation technologies on its dry bulk vessels. Under a memorandum of understanding, the companies will adopt two approaches, Kongsberg explained.

The first will be to evaluate and test emerging decarbonisation technologies for use in shipping. The second will be to integrate both emerging and existing technologies into deployable systems that can be installed on Berge Bulk's fleet of more than 80 dry bulk vessels.

Commenting for Berge Bulk at the time, Marshall said: "Berge Bulk is actively engaged in identifying new emerging technology trends to help us reach our zero-carbon goals. However, there are plenty of existing technologies that we can and should be leveraging today to reduce our vessel emissions now."



Shipping needs to be cleaner and more sustainable; hybrid power systems are one means to achieve this Source: IMO

Meeting demand for low-emission, high-efficiency propulsion

HYBRID POWER The combination of new and existing technologies can make a major contribution to cleaner operations but safety issues must be understood and addressed, writes Modesto Lezama, managing principal engineer, ABS

Hybrid power systems are defined as the combination of new and conventional technologies that make possible electric power generation in vessels for higher performance, greater efficiency and lower greenhouse gas emissions. Energy storage systems such as lithium-ion batteries, in combination with diesel engine generators, dual-fuel engines and shaft generators will continue to follow this path within the maritime sector. This supports efforts to meet emissions reduction targets and achieve key performance indicators for owners, operators, designers and integrators, and classification societies in their initiatives to improve safety, operability and reliability of assets.

Expanding capability

The concept of integrating hybrid-electric power systems with conventional power sources and the use of energy storage systems such as batteries, has become more attractive to vessel owners in recent years. However, some demonstration projects using fuel cell technologies in the maritime industry are getting noticed, too.

The main hybrid power system concepts are the integration of conventional sources (diesel engine generator sets, gas turbine generators, dual-fuel engines with or without shaft generators) and new technologies such as fuel cells, energy storage systems (batteries and supercapacitors) and in the future photovoltaic solar, wind and flywheels.

Currently, lithium-ion battery technology still dominates the use of energy storage systems. ABS expects more applications in the maritime sector, where battery systems based on solid state technology, metal-air, lithium-sulphur (Li-S) will become part of the ecosystem once more research, development and testing have taken place.

Optimising installations

Classification societies will continue to play a key role in the assessment and verification process, providing rules and guidance to help the industry adopt the safest

and most appropriate combination of those technologies.

The power generated from the combination of devices, machinery and systems results in electric and mechanical power required to supply electrical loads and propel vessels. Theoretically, most vessels can be equipped with a combination of technologies. However, there are several limitations such as maturity of technology, availability of bunkering systems, safety constraints, vessel structure, design, layout and operational profiles that may complicate the process.

It should be noted that battery system configurations require detailed design studies including simulation and optimisation processes for the integration with other technologies.

The operating guidance, maintenance and inspection plans provided by battery systems' vendors are very important to understand the life cycle of the batteries. Procedures are typically based on a manufacturer's own and other recognised standards. This documentation should be considered for all maintenance regimes.

Prioritising safety

Battery systems such as lithium-ion types have known safety issues such as thermal runaway and the risk of fire or explosion, potentially causing injuries to personnel. The thermal runaway reaction in the battery cells can lead to battery failure and potential ignition of the electrolyte separator and electrodes, causing a fire in the battery system. Battery management systems and fire protection systems must be in place to prevent this from happening and prevent further damage in the event of thermal runaway.

Some research indicates lithium-ion batteries may have nearly reached their theoretical limit in energy and power density. This may limit their potential for maritime applications where higher power and energy levels are needed, and it may accelerate the research and development of other battery chemistry technologies in the medium term. Potential alternatives to lithium-ion batteries are in different stages of research, but they may show promise for battery systems to become more practical and widespread in maritime applications in the future.

With regard to installation of fuel cell power systems, this will have to go through a rigorous design and risk assessment process prior to their installation on marine assets where personnel or crews are part of the daily operation. A maintenance and operational plan including emergency response is required and emergency operational procedures are necessary for fire-fighting and abandonship scenarios.

In the case of battery charging, procedures necessary for shore power options need to be clearly established and conducted in coordination with service providers.

The more the maritime and offshore industries participate in the adoption of hybrid electric power systems, the safer, more mature and easier to adopt these new technologies will become.

Next generation technologies

As mentioned above, in addition to lithium-ion type batteries, research and development of several other battery technologies continues and is likely to evolve for deployment in the maritime industry in the future. The use of biofuels, their contribution to the development of more dual-fuel engine types also will be a big contributor to this process. Owners and operators will need to coordinate their efforts with classification societies to apply the rules and guidelines that will enable safe installations in the field.

While hybrid systems can contribute to the reduction of fuel consumption and greenhouse gas emissions so that hybrid systems can be more sustainable, there is a need for efficient and sustainable battery technologies that can provide the required power.

The enhancement of battery systems will also enable renewable energy to be further implemented, potentially reducing emissions further. As emphasis continues to increase on reducing environmental impact, this may be an essential technology for an eventual shift to more hybrid or even all-electric vessels.

To enable owners to understand the potential of hybrid systems – as well as the required safety management processes – ABS has published an Advisory that offers an overview on hybrid electric power systems, the current status of the component technologies, the advantages and challenges of each, along with some of the applications in the marine and offshore industry. The study explores the advantages and challenges that come with hybrid systems on vessels, looking at technologies like solar energy and fuel cells that may be useful in such a system.

Dry bulk operator to use new low-carbon fuel in piloting phase

ESL Shipping will become the world's first shipping company to start using new low-emission Neste Marine™ 0.1 Co-processed marine fuel in its vessels in Finland and Sweden

EMISSIONS REDUCTION | Finnish dry bulk owner, ESL Shipping, is to start using a new fuel developed by energy company, Neste Oyj, which offers 80% reduced greenhouse gas emissions over its life cycle and does not require modifications to ships' engines. The Neste Marine™ 0.1 Co-processed fuel will be used in the shipping company's vessels in Finland and Sweden.

The fuel is produced at Neste's refinery in Porvoo, Finland, which the energy company plans to make Europe's most sustainable energy plant by 2030. Neste has also pledged to achieve carbon-neutral energy production by 2035.

The ISO 8217-compliant drop-in fuel has International Sustainability and Carbon Certification (ISSC) PLUS validation and is currently in its piloting phase. In the refining process, Neste replaces some of the fossil raw materials with sustainable ones refined by the energy company. They include waste, residues, and other non-fossil raw materials including sustainable feedstock for plastics and other products. The result is a fuel that has a similar composition to conventional bunker fuels.

ESL Shipping managing director, Mikki Koskinen, said: "The co-processed marine fuel is something we have been waiting for a long time. ESL Shipping is committed to leading the way in reducing greenhouse gas emissions of the maritime industry, and we are now fortunate to be able to use this low-emission alternative without having to do any fleet modifications. We believe this is the right thing to do, and I'm convinced we in the Nordics are well-positioned to show the way for the global maritime industry."

Neste's head of Marine Fuels and Services, Sveta Ukkonen, commented: "Supporting the shipping industry towards carbon neutrality requires partnerships, all available solutions, and further innovations. We are proud of the solutions we have provided to the global aviation and road transport sectors to reduce greenhouse gas emissions, and it is a big step for Neste to be able to offer similar solutions to maritime transport, too. After all, as 90% of world trade and 13% of global transport emissions are the result of the shipping industry, it needs lower-emission solutions that are available already today."

ESL Shipping, a subsidiary of Finland-based Aspo plc, focuses on dry bulk movements in the Baltic region. Together with AtoB@C Shipping, a group company, it controls a fleet of 48 vessels ranging in size from 3,000 to 56,000dwt.

New guidelines on bunker tank composition

CONTAINMENT SYSTEMS | Korean Register (KR) has published new guidelines on the materials used in storage tanks for new low- or zero-carbon fuels currently under development. Its 'Guidelines for Selection of Metallic Materials of Containment Systems for Alternative Fuels for Ship' have been drawn up jointly by the Register's research and development (R&D) division and the research team at the Korea Institute of Machinery and Materials.

In a statement, KR noted that in the run-up to new IMO regulations in January 2023, ship operators are adopting a range of strategies such as engine power limitation, voyage optimisation, and the installation of energy saving devices to reduce carbon emissions. However, in the longer term, new marine fuels will be adopted, and some of these will have implications for the materials used to manufacture containment systems, as well as their supporting structures.

The guidelines assess the tank containment material options for fuels including ammonia, biogas, hydrogen and methanol. Of these, hydrogen is technically the most difficult to store in large quantities because gaseous hydrogen can damage some materials.

Executive vice president of KR's R&D division, Kim Daeheon, commented: "KR conducts world-class research and development to benefit and support the wider maritime industry, regularly sharing its latest technological information. These timely guidelines will be welcomed by universities, research institutes, shipowners and clients, indeed anyone who is working to develop eco-friendly vessels."

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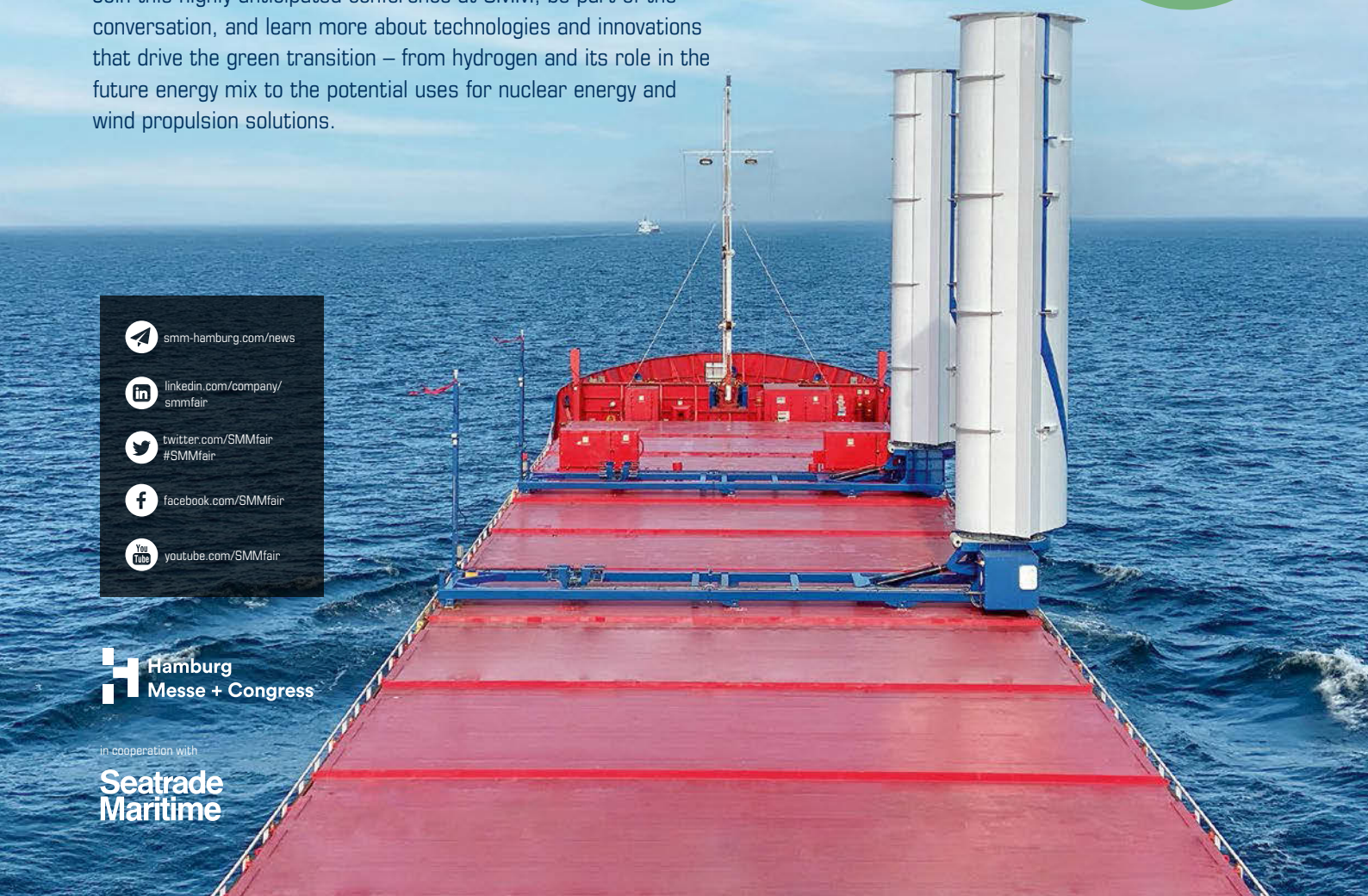
Towards zero emissions

gmec – the global maritime environmental congress, brings together leading experts to assess the industry's decarbonisation progress and ambition as well as to discuss commercial challenges and path breaking solutions on the way to a more sustainable shipping.

Join this highly anticipated conference at SMM, be part of the conversation, and learn more about technologies and innovations that drive the green transition – from hydrogen and its role in the future energy mix to the potential uses for nuclear energy and wind propulsion solutions.



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What decarbonisation means for cylinder oils

The White Paper examines the role of cylinder lubrication when it comes to new fuels and engine designs. Pictured is the methanol dual-fuelled MR product/chemical IMO type 2/3 tanker *Mari Innovator*. Source: Chevron

WHITE PAPER | A new report from Chevron Marine Lubricants assesses the implications for future formulation of cylinder oils from emerging engine designs and increasing use of sustainable fuels. The White Paper titled 'The Future of Marine Two-Stroke Engine Lubrication' drew on input from engine designers, MAN Energy Solutions and WinGD, as well as the International Council on Combustion Engines, CIMAC.

The white paper concluded that ship operators will need to prioritise thermal resilience, low ash formulation, and high cleaning performance when they choose cylinder oils in future. Future fuels may be dominating discussions across the industry at present, experts noted, but advancing engine efficiency will be equally important in the composition of cylinder oils and their operational performance. Higher temperatures and pressures needed for higher efficiency will set new requirements for oils, they wrote.

In addition to engines designed for new fuels, the increasing use of exhaust gas aftertreatment systems will also have an impact on cylinder oil composition, accelerating demand for low-ash oils. Aftertreatments will be more widely used to reduce pollutants including SOx, NOx, and in future, perhaps carbon. Post-combustion systems can be sensitive to ash deposits and new cylinder oils will need to be formulated with this in mind.

Chevron Marine Lubricants' general manager, Pat McCloud, said: "Our mission is to help navigate uncertainty, delivering robust and reliable lubricant performance to keep engines operating cleanly whatever the fuel, whatever the design. This paper highlights the emerging needs that Chevron Marine Lubricants will have to fulfil to meet that mission."

Joint study completed on ammonia as fuel

SAFETY RISKS | Classification society Bureau Veritas (BV) and energy major, TotalEnergies, have completed a preliminary study assessing the potential health and safety risks from ammonia leaks to crew and passengers, when the compound of nitrogen and hydrogen is used as a marine fuel.

A key focus of the study has been leak mitigation and treatment. The investigation assessed different types of single-wall and double-wall containment systems, the efficiency of ventilation and vapour-processing systems during bunkering operations, the size of safety zones, and health risks to anyone exposed to a leak.

Although ammonia is seen as a promising future marine fuel because it is a zero-carbon source of power from well to wake when produced using renewable energy, it is highly toxic. If inhaled in sufficient quantity, it can cause burning and swelling in the airways resulting in significant lung damage.

Using methodology designed to support the development of LNG last decade and BV's own Rule Note NR 671 on preventing ammonia leaks and requirements for vapour processing systems, the partners were able to compare the two fuels by assessing what concentrations of ammonia in the air could be dangerous. They found that LNG becomes dangerous at about 50,000 parts per million (ppm) while ammonia has health impacts from 30 ppm in cases of permanent exposure, or about 300 ppm when exposed for one hour.

The assessment confirmed findings used as the basis for BV's NR 671, namely that more stringent leak management and vapour gas processing systems are needed. Safety distances should also be much greater for ammonia than LNG.

Commenting on the finding, BV Marine & Offshore's senior vice president Technical & Operations, Laurent Leblanc, said: "While further experimentation and analysis are required to reach definitive conclusions, this preliminary study helped identify future areas to explore for de-risking ammonia as fuel. Additional tests could be performed for leak design scenarios, bunkering safety zones, bunkering arrangements, and the effect of weather conditions, for example.

"Until technology developments can eliminate ammonia leaks completely, leak mitigation and treatment remain the best course of action for shipowners and designers. Our preliminary study with TotalEnergies forms a strong basis for future industry collaboration. By pairing the right questions with the right tests, marine stakeholders can begin the journey to de-risking ammonia as fuel, as they did for LNG."

Carbon credits a source of funding for retrofits

GREENSCREEN | Maritime consultancy, Marsoft Inc, and carbon credits specialist, ClimeCo LLC, are to work jointly on expanding the range and value of Marsoft's GreenScreen carbon credit services so that so-called Gold Standard credits can be used to help fund carbon-cutting retrofit investment in shipping. The companies intend to provide effective systems for carbon emissions reduction verification, credits issuance, and monetisation, and said that they are willing to invest alongside shipowners to reduce CO_2 emissions.

Arlie Sterling, president of Marsoft, said: "Carbon credits can be an important source of funding for retrofits that reduce fuel consumption and CO_2 emissions. Gold Standard certification of those reductions gives owners access to the rapidly expanding voluntary carbon market … Marsoft and ClimeCo will make carbon credits part of the industry-wide solution to the challenge of decarbonisation."

ClimeCo CEO and president, Bill Flederbach, set out benefits of the companies working together. "We will deliver substantial cost and time savings while enhancing value to those customers who take advantage of GreenScreen. ClimeCo is putting its 17 years of experience and unmatched carbon trading scale and expertise behind shipowners and their determination to decarbonise their business. ClimeCo's deep carbon market expertise and relationships will maximise the value of their carbon credits."

Erika Shiller, vice president of Project Development at ClimeCo, commented: "Leading shipowners have already signed up for GreenScreen and have already budgeted a million-tonne reduction in CO_2 emissions over the next five years. The Marsoft/ClimeCo team will establish a high value/high liquidity presence in the carbon markets for credits from shipping. GreenScreen is proven and unique, and we are committed to making it even better by teaming with Marsoft."

Study claims significant CO_2 cuts with just-in-time arrivals

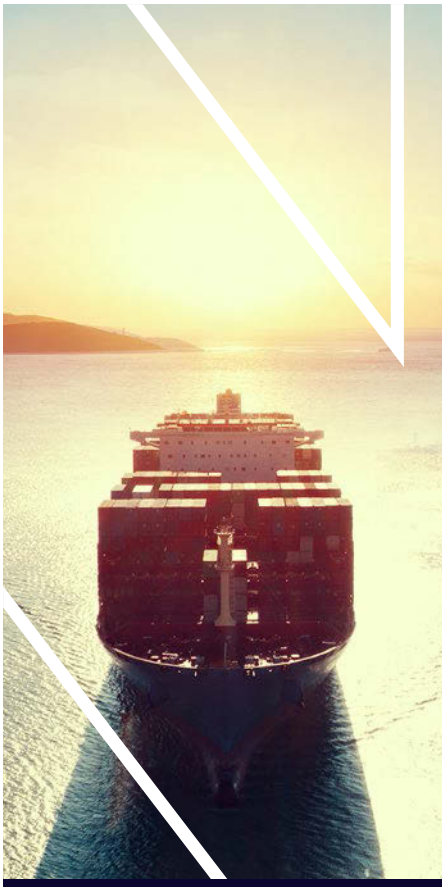
SPEED OPTIMISATION | Container ship operators could cut fuel consumption and carbon emissions by 14% per voyage by using just-in-time (JIT) arrivals, a new study has revealed. Commissioned by the IMO-Norway GreenVoyage2050's Global Industry Alliance to Support Low Carbon Shipping (Low Carbon GIA), the study emphasised how JIT arrivals represent an important tool in achieving the best carbon intensity indicator (CII) ratings, due to enter force for all ships of more than 5,000gt in January 2023.

Carried out by MarineTraffic and Energy and Environmental Research Associates, the study assessed the potential for JIT arrivals to save fuel. AIS data from the pre-pandemic year of 2019 was used to examine the impact of optimising voyages in three scenarios – the entire voyage, the last 24 hours of a trip, and the last twelve hours.

The first scenario demonstrated the largest average fuel savings of 14.16%. However, even using JIT arrivals for the last parts of the voyage achieved significant savings of 5.9% over 24 hours, and 4.23% over 12 hours.

Capt. Andreas M. van der Wurff, chairman of the Low Carbon GIA Ship-Port Interface workstream and Port Optimisation manager at A.P.Møller-Maersk, declared: "In fighting climate change, global shipping has a steep mountain to climb, and we need to pull all levers to deliver in line with the Paris Agreement. The study underlines that while we work to accelerate and scale the availability of the future green fuels, in the short-term significant emissions reductions can be achieved by bringing vessels, terminals and ports together to exchange standardised data and facilitate just-in-time arrivals."

Low Carbon GIA, established in 2017, is a public-private partnerships which aims to develop initiatives to address common barriers to shipping's decarbonisation. In 2020, it published the 'Just In Time Arrival Guide – Potential Barriers and Solutions'. It now operates under the framework of IMO-Norway GreenVoyage2050 Project.



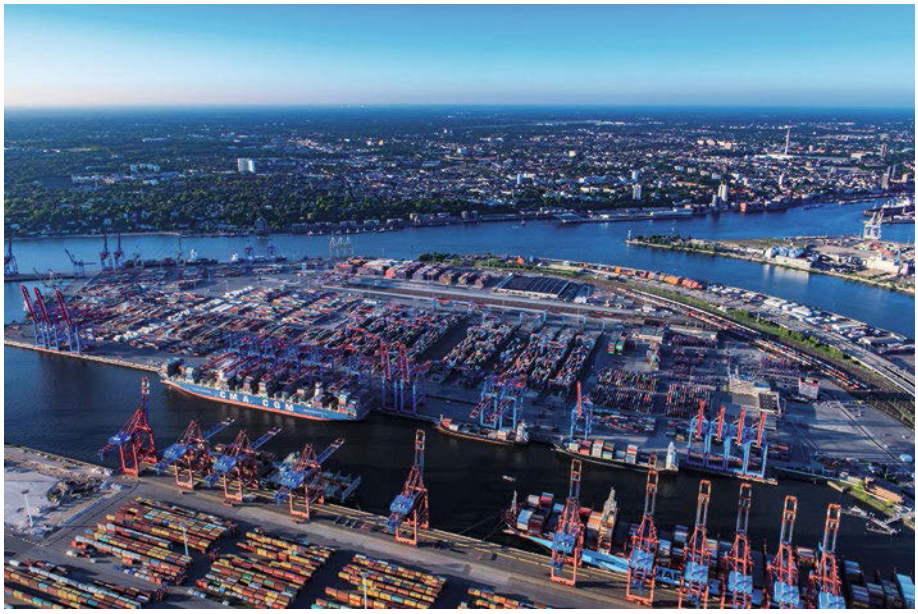
Maximum terminal efficiency

TRUCK FIT | Working together with several haulage companies, Hamburger Hafen und Logistik AG (HHLA) has continued to refine its slot-booking system, Truck FIT, to improve utilisation at its Hamburg container terminals and raise efficiency at the land-sea interface.

The initiative follows a spell of unprecedented supply chain disruption at ports in many parts of the world, resulting in delays to ships costing billions of dollars. Productivity both at sea and onshore has been seriously affected and the disruption is likely to continue for months to come, experts say.

The Truck FIT system is designed to ensure optimal use of available capacity at terminals by providing an equal opportunity to all haulage companies to plan and book slots. This has the potential to reduce truck time in terminals and raise productivity. Following the last system update, the 'no-show rate', which includes cancellations and unused slots, has continued to fall, HHLA said.

Managing director of Hamburg's Container Terminal Altenwerder, Oliver Dux, commented: "We are very grateful to our project partners ... for supporting HHLA's introduction of Truck FIT despite the difficult circumstances. The current situation, in particular, illustrates how important it is for all parties that are affected by the supply chain disruptions to work together and to find solutions."



Aerial view of HHLA Container Terminal Burchardkai in Hamburg Source: HHLA

The slot-booking process was introduced in the Port of Hamburg in 2017 to prevent bottlenecks at the terminals.

Ship manager offers hands-on help focusing on EEXI and CII compliance

FLEET PERFORMANCE | As the clock ticks down to the IMO's new emission regulations in January 2023, Bernard Schulte Shipmanagement (BSM) has broadened the capabilities of its in-house Fleet Performance Centre. The company aims to provide more support for owners as they prepare for the Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII).

Shipowners with vessels of more than 5,000gt will be affected by the new regulations and, if they have not done so already, they must take urgent action to comply with new carbon efficiency measures or face operational restrictions and, potentially, financial consequences, BSM said in a statement. The company is now offering to help them with a combination of vessel performance monitoring, decarbonisation management, data collection, and data analytics, managed out of its own Fleet Performance Centre (FPC).

A range of support systems has been introduced, including new technical consultancy services to help owners in their compliance procedures. Meanwhile, a real-time monitoring capability at the FPC will identify and separate fuel consumption contributors such as hull, machinery, route, and weather. The FPC is also engaging with charterers to establish communication protocols leading to voyage optimisation, a key element of the CII assessment process.

"These new regulations call for a more proactive approach towards managing carbon intensity while encouraging data transparency," declared Anil Jacob, the ship manager's head of Fleet Performance. "Our aim is to enable our crews on board, shipowners, and charterers to make data-driven decisions for most efficient vessel operations that reduce their environmental impact and comply with, or even go beyond, the requirements of international regulations.

"Ultimately," he continued, "the EEXI and CII measures seek to develop a mindset of continuous benchmarking and improvement, such that it provides a case for vessel or operational modifications to bring down on-board carbon emissions. These capabilities at the Fleet Performance Centre will be of value to any shipowner, regardless of their fleet size."

BMS currently manages a fleet of more than 650 ships, with over 20,000 seafarers and 2,000 shore-based employees. The company has eleven ship management centres, 25 crew service depots, and four wholly-owned maritime training establishments.

Ship&Offshore Buyer's Guide

The Buyer's Guide serves as market review and source of supply listing. Clearly arranged according to references, you find the offers of international shipbuilding and supporting industry in the following 17 columns.

2 Propulsion plants

2.02 Gears

REINTJES GmbH
REINTJES POWERTRAIN SOLUTIONS
Eugen-Reintjes-Str. 7
D-31785 Hameln
Tel. +49 (0)5151 104-0
Fax +49 (0)5151 104-300
info@reintjes-gears.de • www.reintjes-gears.com

Propulsion systems with power ratings from 250 up to 30,000 kW

2.03 Couplings + brakes

R+W Antriebselemente GmbH
Hattsteinstraße 4
63939 Wörth am Main / Germany
Fon: +49 (0)9372-9864-0
Fax: +49 (0)9372-9864-20
email: info@rw-kupplungen.de
www.rw-kupplungen.de

Couplings, seawater resistent

2.04 Shaft + shaft systems

Piening Propeller
Am Altendeich 83 • D-25348 Glückstadt
Tel. +49(0)4124 91 68-0 • Fax +49(0)4124) 37 16
e-mail: pein@piening-propeller.de
Internet: www.piening-propeller.de

Fixed and Controlable Pitch Propellers, Shaft Gears, Gearboxes

2.05 Propellers

Piening Propeller
Am Altendeich 83 • D-25348 Glückstadt
Tel. +49(0)4124 91 68-0 • Fax +49(0)4124) 37 16
e-mail: pein@piening-propeller.de
Internet: www.piening-propeller.de

Fixed and Controlable Pitch Propellers, Shaft Gears, Gearboxes

3 Engine components

3.05 Starters

DÜSTERLOH Fluidtechnik GmbH
Abteilung Pneumatik Starter
Im Vogelsang 105
D-45527 Hattingen
Tel. +49 2324 709 - 0 • Fax +49 2324 709 -110
E-mail: info@duesterloh.de • www.duesterloh.de

Air Starters for Diesel and Gas Engines up to 9.000 kW

3.07 Filters

BOLLFILTER Protection Systems
Boll & Kirch Filterbau GmbH
Siemensstraße 10-14 • 50170 D-Kerpen
Tel.: +49 2273 562-0 • Fax: +49 2273 562-223
E-Mail: info@bollfilter.de • www.bollfilter.de

Applied filtration technology for marine engines and maritime water management

FIL-TEC Rixen GmbH
Osterrade 26
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Fax +49 (0)40 656 57 31
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E-Mail: info@hydac.com • www.hydac.com

Fluid management for heavy diesel engines

SOLBERG
Ölnebelabscheider
Solberg International GmbH
Schwarzenbrucker Str. 1
90537 Feucht
Tel: +49 9128 7080 537
vertrieb@solbergmfg.com • www.solberg-filter.de/oelnebel
Filtersysteme für Schiffsmotoren, Gas & Dampfturbinen

3.10 Injection systems

WOODWARD L'orange
Porschestrasse 8 • 70435 Stuttgart
Tel. +49 711 8 26 09 - 0
sales@lorange.com • www.lorange.com

Engine components and control systems for large engines from 1,000 to 40,000 kW

4 Corrosion protection

4.01 Paintings

International Farbenwerke GmbH
Bereich Schiffsfarben
Sachsenkamp 5 • D-20097 Hamburg
Tel. (040) 720 03 122 • Fax (040) 720 03 110
e-mail: iphamburg-marine-orderdesk@akzonobel.com
Internet: www.international-marine.com

Marine Coatings

5 Ships' equipment

5.03 Refrigeration • HVAC

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Freudenberg
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Tel.+49 (0)6201 7107 264
Weinheim / Germany
viledon@freudenberg-filter.com
www.freudenberg-filter.com

Filters for intake air filtration of gas turbines, turbo chargers and HVAC systems

5.06 Furniture + interior fittings

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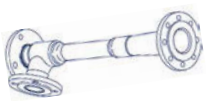

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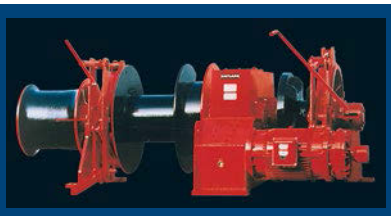

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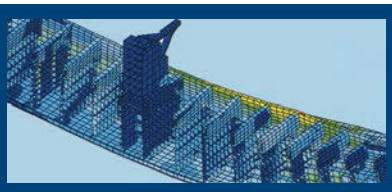

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Multi-course plan needed

DIVERSIFICATION Energy efficiency is a critical component of decarbonisation and with increased regulations shipowners should be implementing a multi-course plan of action to reduce emissions drastically by 2025. Companies are well advised to take a broad approach to their production and service portfolios, writes Andrew Marshall, CEO of US-based ballast water treatment (BWT) specialist, Ecochlor.

Ecochlor's ballast water management system offers shipowners the flexibility to choose the best system for their vessel's operation

Source for all images: Ecochlor

There are various straightforward options available to reduce fuel consumption – ranging from slow steaming, weather routing, ballast water/trim to "air lubrication", which reduces frictional resistance between the hull and seawater.

The air lubrication approach to reducing CO_2 is achieved by creating a film of bubbles along the ship's flat bottom. This reduces drag and fuel consumption as well as associated emissions, in addition to any improvements already achieved in other areas, as mentioned above.

Armada Technologies, a UK-based company to which Ecochlor offers technical assistance and global sales and marketing support, has developed a hull air lubrication system and is bringing it to market in the near future. This air lubrication system is expected to deliver estimated fuel savings of 10-12% depending on hull design, and is effective regardless of fuel type, making it a key technology in transition to zero-carbon fuels. The Armada system has a relatively low installation and operating cost and is simple to maintain.

Alexander Routledge, CEO of Armada explained the concept behind the technology: "Our system is more advanced than any other hull lubrication technology on the market today. Armada utilises the ship's own forward motion to help drive the system. An eductor is used to draw air in, whilst a series of micro-bubble emitters distribute the bubble swarm under the ship. This significantly reduces drag and, due to its unique patented design, uses less power than other hull lubrication technologies, providing an economic payback to the shipowner within a comparatively short period of time."

The environmental impact of de-gassing can reduced with NanoVapor technology

Low energy consumption is key

An oft-overlooked option that can lower fuel consumption and emissions is to ensure that all the systems and equipment on board a vessel are low energy consumers. As environmental maritime regulations get stricter, equipment for ships with increased energy efficiency will be in high demand.

The lower the energy demands for equipment on a ship, the lower the fuel consumption, which results in lower operating costs. Whilst energy-efficient products may cost more to purchase initially, they typically save much more money in operational expenses over the life of the vessel.

To explain, the CO_2 footprint of a ballast water management system (BWMS) can be analysed. There are some environmental advantages of the Ecochlor EcoOne® BWMS, filterless along with hybrid variants. This system has very low energy requirements and therefore reduces a ship's total carbon footprint. For example, a system without a filter, for a ship with ballast flow rates between 500 to 3,000m^3/hour, has power requirements that range from 5 to 7 kW; with flow rates between 3,000 to 10,000m^3/hour, the power requirements would range from 10 to 15 kW.

Panos Smyroglou, vice president of Sales and Marketing at Ecochlor, said: "When getting BWMS equipment specifications from makers, shipowners should not only review operating costs, but also ask the hard questions regarding opex for less-than-optimal water conditions for that particular treatment technology. Oftentimes, power consumption increases significantly when the BWMS is operating in challeng-

Schematics of an EcoOne installation

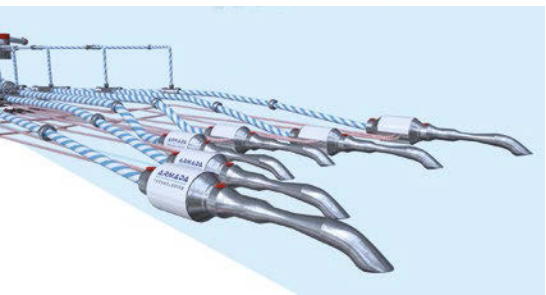
ing circumstances, such as UV systems in 'dirty' water conditions.

"Manufacturers may only offer on paper the power requirements in 'best case' scenarios," Smyroglou continued. "This extra energy usage can have a very real impact on your opex over the long-term, turning that 'bargain' purchase into a disadvantage for the remainder of the life of the vessel. Additionally, ships in many ports will soon be required to use ship-to-shore power to reduce GHG emissions. It makes sense for shipowners to install BWMS with the lowest possible power rating since ballasting operations are handled in port."

CO_2 reduction in de-gassing fuel oil tanks

It is easy to reduce CO_2 on board a vessel by making a simple change in de-gassing procedures. Using NanoVapor technology, a new product available to the maritime industry, the environmental impact of de-gassing can be reduced, less money has to be spent, and a safer environment for the crew is assured.

Using a NanoVapor unit suppresses volatile organic compound (VOC) formation very quickly. After a single venting, the fuel tank is safe to enter and remains that way for a considerable period of time. The tank can then be directly refilled.



Rendering of the Armada Technologies air lubrication system

However, de-gassing without a NanoVapor unit is a very different story. Everything has to be fully drained, including bottom sediments, and then properly disposed of in an eco-friendly way. Prior to entry, venting is required with VOCs polluting the environment. The tank cleaning requires cleaning chemicals and/or hot water and, again, the slops need to be removed by environmentally-approved methods with an outside agency.

"In Central Europe, venting cargo tanks to the atmosphere is illegal depending on the cargo," commented Sören Scheid, NanoVapor brand manager. "Stationary or mobile VOC treatment units have to be used for cargo tank venting. These units recover or incinerate the cargo vapours which also requires external energy sources."

Alternative fuels and scrubbers

The most obvious way to reduce shipping emissions is by using fuels that produce fewer GHGs. In 2020, the IMO enacted new regulations that brought the maximum allowable sulphur content down from 3.5% to 0.5%. Until then, most ships used a low-cost, low-grade fuel oil with a high sulphur content.

When the IMO called for a decrease in GHG emissions, it introduced the Initial IMO GHG Strategy reducing the total annual GHG shipping emissions by 50% from 2008 levels by 2025. Currently, there are many alternative fuel options being explored with LNG, LPG, methanol, biofuel and hydrogen looking the most promising at this time. Whilst not an issue for newbuilds, changing fuels would require an engine conversion for existing ships amongst other shipboard modifications and these can be quite costly. For the used ship market sector, Exhaust Gas Cleaning Systems, or 'scrubbers', may offer an attractive alternative to low- sulphur fuels.

Conclusion

After more than 21 years with a singular focused in the BWMS industry, Ecochlor is diversifying and investing a substantial amount of time, money and resources into researching some of the most innovative "green marine" technologies that are available (or soon to be available) in the market. There is a growing number of environmental pressures being placed on shipowners – whether it is ballast water management, scrubbing, biofouling, or CO_2 emissions management.

Reducing frictional resistance

HYKAT The reduction of skin friction force between a ship's hull and the surrounding water can contribute to minimising fuel consumption and emissions. The Hydrodynamics and Cavitation Tunnel (HYKAT) at the Hamburg Ship Model Basin (HSVA) offers best possibilities to measure the skin friction force at Reynolds numbers close to real operational conditions, write HSVA's Felix Hoppe and Daniela Myland.

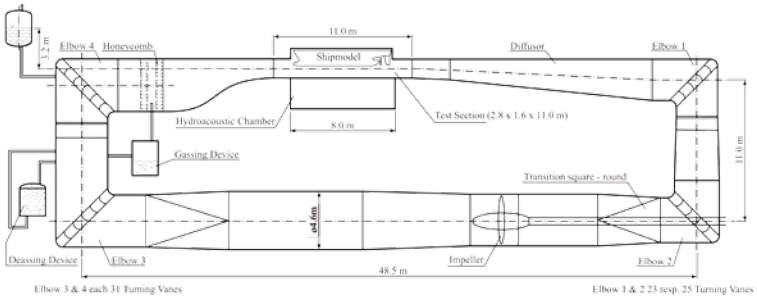


Figure 1: Schematic depiction of the Hydrodynamics and Cavitation Tunnel (HYKAT)

Source for all images: HSVA

The total resistance on a moving ship is determined by a variety of factors such as hull form, sea state, and wind speed and direction. One of largest contributors to the overall resistance are the skin friction forces between a ship's hull and the surrounding water, which can account for up to around two thirds of the total resistance [1].

The skin friction itself is governed by physical properties like ship speed, general surface roughness or fouling attached to the hull and has been the subject of numerous studies before. Those led to well-known correlations for the frictional resistance coefficient C_F, which describes the magnitude of the friction in a dimensionless form. Prominent examples are the famous relations by Prandtl [2], Schlichting [3] or the ITTC [4].

To reduce power consumption, the average ship speed has decreased over the last decade shifting frictional resistance components into the focus of efforts to reduce further overall fuel consumption and the related emissions. Hence, considerable efforts have been made in recent years to reduce the impact of skin friction. Examples include various air lubrication systems, which are designed to actively reduce friction by air in the ship's boundary layer.

Other approaches revolve around the idea of developing ship coatings, which can cut resistance based on their physical properties. Examples for these passive systems are the coatings developed during research projects such as AIRCOAT [5], eSHaRK [6] or FLIPPER [7].

In all cases, the goal is to alter the complex interaction of the fluid flow with the ship's hull in a beneficial way. Hence, in order to advance these friction-reducing technologies, exact measurements of the friction force are required.

Investigations of the skin friction should be carried out using Reynolds numbers (Re) which should be as large as possible to be most relevant to the full-scale application/problem. However, due to restrictions in size and speed, in most experiments the Reynolds number is usually several orders of magnitude too small to fulfill this requirement, i.e., while in full scale Re is of order of magnitude $O(10^8)$ most experiments only achieve a maximum order of $O(10^6)$. However, there are now two possibilities for measuring the skin friction force at Reynolds numbers close to real operational conditions using the Hydrodynamics and Cavitation Tunnel (HYKAT) at the Hamburg Ship Model Basin (HSVA). Both possibilities have been applied during the AIRCOAT research project.

Test setups

The experiments are conducted in HYKAT, the largest cavitation tunnel available at HSVA, see Figure 1. Its test section is 11m long, 2.8m wide and 1.6m high, and allows for the installation of whole ship models as they are used for tests in the large towing tank or the large ice tank of HSVA. The test section is used to install the aforementioned large friction measurement setups: a flat plate setup and a torpedo-shaped setup.

The flat plate arrangement is shown in Figure 2 as it was used during HYKAT tests for the AIRCOAT project. As the name suggests, the setup consists of a flat plate which is flush-mounted to the ceiling of the HYKAT test section and which can be laminated with different coatings. The whole setup is mounted in a force balance measuring the total friction forces in the streamwise direction. The base plate is 7.8m long and 1.8m wide, resulting in a total area of about 14.0m^2. Combined with a maximum water velocity of about 10m/s, large Reynolds numbers of order $O(10^7)$ are achievable.

The second option for friction measurements in the HYKAT is shown in Figure 3: the torpedo-shaped test body. The test setup consists of a cylindrical test body, which can be laminated with various coatings. The setup is suspended from the ceiling of the HYKAT test section and houses a force balance measuring the total force on the test body (cylindrical part and torpedo front) in the streamwise direction. The overall length of this system is 7.4m, where

Figure 2: Flat plate setup for friction measurements. Here the surface is covered with AIRCOAT foil.

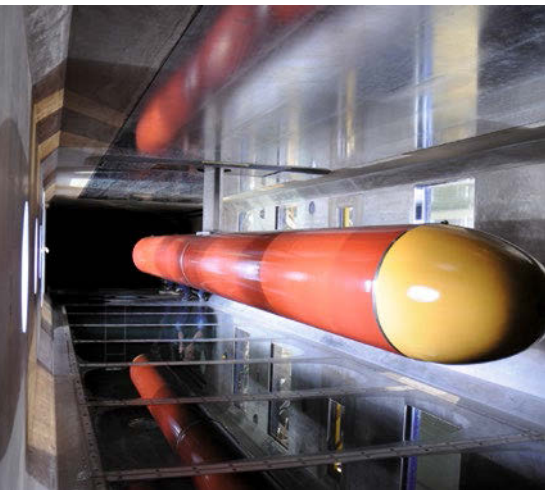


Figure 3: Torpedo-shaped test setup for friction measurements. Picture taken during friction measurements for the AIRCOAT project.

the cylindrical, laminated part is about 6m long and has a diameter of 0.5m resulting in a total area of about 9.4m². Using the length of the system, again high Reynolds numbers of order O(10^7) are achievable.

Discussion of the test setups

Both test arrangements enable large Reynolds numbers to be obtained, making them suitable for near-operational measurements of frictional resistance. The main differences are the respective installation processes and the corresponding scope of application.

In the torpedo-shaped setup, the investigated surface can be readily changed by taking the whole setup out of HYKAT and switching out the cylindrical covers of the force balance. Consequently, a large variety of different surfaces can be tested and set-up time of the experiment can be shorter. While the force balance itself is highly accurate (as is the one used in the flat plate setup), the forces measured by this setup are the total forces on the torpedo-shaped test body, i.e., they consist not only of the friction forces on the cylindrical parts but also include form or pressure drag.

Therefore the skin friction force has to be indirectly determined by extraction from the total force. The following procedure is used, which is described relying on data from the AIRCOAT research project. The existence of the critical air layer could not be determined during the experiments, and it is possible that a (partial) loss of the air layer occurred, explaining the small difference between AIRCOAT foil and the theoretical curve.

In a first step, measurement of the total resistance of the torpedo is carried out using a reference material as coating (see Figure 4a for an example). As mentioned the resulting force, $F_{T,Ref}$ consists of the frictional resistance $F_{F,Ref}$ as well as all remaining form dependent resistances $F_{R,Ref}$, i.e., $F_{T,Ref} = F_{F,Ref} + F_{R,Ref}$, which explains why in Figure 4a the total resistance forces are larger than the frictional forces given by the ITTC 1957. It is then assumed that for the reference case, the frictional resistance is given by the theoretical friction line by the ITTC, 1957:

$$F_{F,Ref} = F_{F,ITTC} = C_{F,ITTC} \frac{\rho}{2} A\, u^2$$

$$\text{with } C_{F,ITTC} = \frac{0.075}{(\log_{10} Re - 2)^2}.$$

Based on this assumption it is possible to estimate the remaining friction forces $F_{R,Ref}$ by subtracting the estimated frictional resistance from the total resistance of the reference measurement: $F_{R,Ref} = F_{T,Ref} - F_{F,ITTC}$. In a next step the assumption is made that $F_{R,Ref}$ is identical for all investigated coatings. Since the form of the torpedo-shaped force balance does not change from one coating to another, this is a reasonable assumption.

Consequently, the frictional resistance F_F and from that the corresponding frictional resistance coefficient C_F can be determined by subtracting $F_{R,Ref}$ from the respective total resistance force of the investigated case: $F_F = F_T - F_{R,Ref}$. In Figure 4b, the estimated frictional resistance coefficient $C_{F,AIRCOAT}$ is compared with $C_{F,ITTC}$. It is apparent that for Reynolds numbers of more than 4.0 x 10^7, the AIRCOAT foil leads to a reduced frictional resistance compared to the reference case.

The main advantage of the flat plate setup is its shape. Due to the arrangement, the setup accurately represents the flat parts of a ship. Furthermore, the desired friction force values can be obtained directly, i.e., the measured forces are the frictional forces which can be determined with high accuracy.

Therefore, the results can be compared directly with reference measurements or theoretical values like the curve of the frictional resistance by the ITTC 1957 shown in Figure 4a. Minor downsides of this setup are that the preparation of the flat plates is time-consuming, and the coated plates cannot be replaced by other plates with different coatings as easily as in the torpedo-shaped setup.

Conclusion

HSVA has two highly sophisticated possibilities available for measuring friction forces at Reynolds numbers close to real operational conditions. The flat plate setup can directly determine the skin friction on the surface but is more time-consuming in its application. For tests with a number of different surfaces, a torpedo-shaped setup enables the investigated coating to be changed easily.

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[7] Schrader, Lars-Uve. Passive Drag Reduction via Bionic Hull Coatings. J Ship Res 63 (2019): 206 – 218. doi: https://doi.org/10.5957/JOSR.09180068

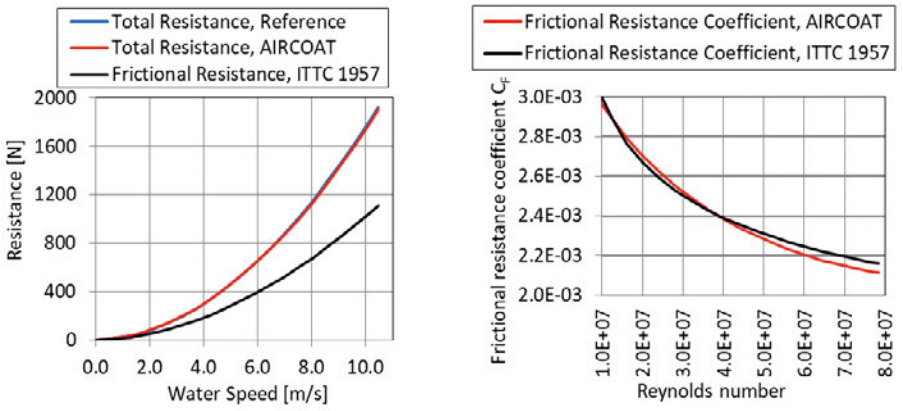

Figure 4a (left): Total resistance forces measured by the torpedo-shaped test setup for AIRCOAT foil and a reference. Theoretical flat plate frictional resistance by the ITTC 1957 as reference. Figure 4b (right): Frictional resistance coefficient C_F for the AIRCOAT foil in comparison with the theoretical ITTC 1957

The efficacy of capture

IN-WATER CLEANING In order to verify the efficacy and compliance with threshold values of in-water cleaning of ship hulls, one option is to examine the relation between fouling stage and weight of fouling, write Burkard Watermann, and Anja Thomsen from the Hamburg-based research institute LimnoMar; and Jens Wallis and Bernd Daehne from Dr Brill + Partner, Institute for Antifouling and Biocorrosion, Norderney

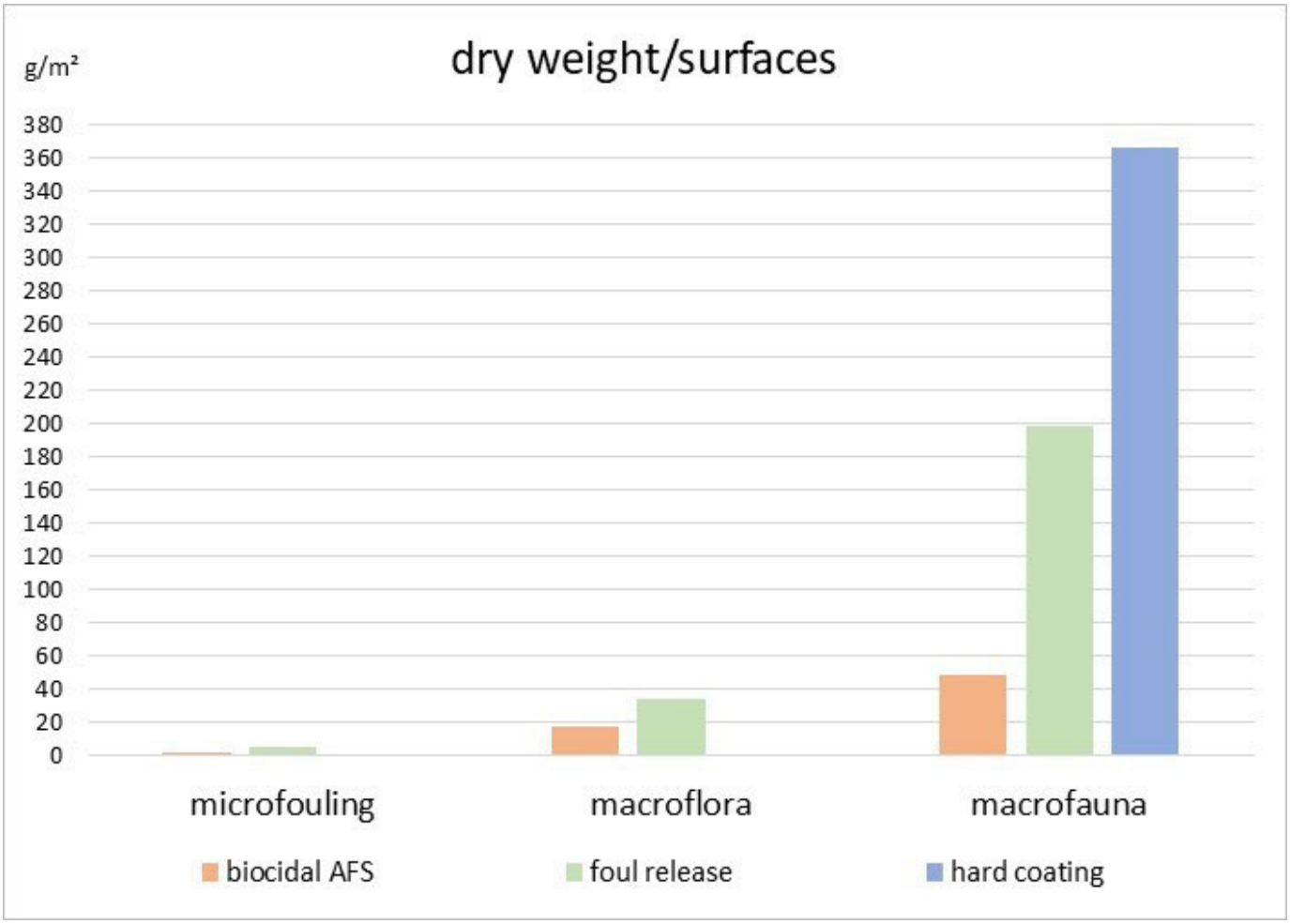

Figure 1: Relation between dry weight of fouling (arithmetic mean) on biocidal antifouling paints, foul release and hard coatings. On hard coatings, microfouling and macroflora weight was not measured. Source: LimnoMar

In-water cleaning of ship hulls is widely carried out to increase ship performance, and is under intense discussion regarding regulations, quality improvement and technologies in use [2]. One critical aspect is the common practice of cleaning biocidal antifouling paints, which is incompatible with national and EU water legislation, and the impact of abrasion on antifouling coatings that are not designed for cleaning.

Additionally, the majority of cleaning operations do not filter or capture the fouled material. Furthermore, there is usually no control or verification of the quality of the cleaning technology applied. Fluorometric technologies are used to control the efficacy of capture. Ideally, the removed fouling should be captured and sucked up by the cleaning machine using a vacuum system.

In waters with high visibility, optical methods like front and aft cameras can be used. Dyes can be injected to control the efficacy photometrically [9]. Unfortunately, in ports along the North Sea and most ports of the Baltic Sea, the visibility is low and optical control methods cannot be applied, requiring other verification methods.

One option is to use the relation between fouling stage and weight of fouling as an indicator of the amount of fouling which has to be captured. Taking samples of the fouling accumulation prior to cleaning may provide a guide to the volume of fouling present on the hull and the amount to be captured.

In this way, the captured material can be compared with the earlier estimate and may provide a reasonable estimation of efficacy. To explore the validity of the relationship between fouling stage and fouling weight, data from previous fouling studies were compiled and scrutinised regarding their usefulness for such an estimation.

Fouling stage	N (45)	Biocidal antifouling paints	
		Dry weight (g/m²) Arithmetic Mean (min - max)	Ash dry weight (g/m²) Arithmetic Mean (min - max)
Microfouling	12	1 (1 - 1)	n.d.
Macroflora	23	18 (1-105)	4 (1-8)
Macrofauna	10	49 (1-210)	14 (5-21)

Table 1: Dry and ash dry weight in relation to fouling stage on biocidal SPCs

Source: LimnoMar

Fouling stage	N (163)	Foul release coatings	
		Dry weight (g/m²) Arithmetic Mean (min - max)	Ash dry weight (g/m²) Arithmetic Mean (min - max)
Microfouling	8	5 (1 - 25)	1 (1-1)
Macroflora	10	34 (9-81)	3 (1-5)
Macrofauna	145	199 (1-2,221)	18 (1-53)

Table 2: Dry and ash dry weight in relation to fouling stage on foul release coatings

Source: LimnoMar

Materials and methods

In total, 363 datasets taken during research projects between 1998 and 2002 were evaluated with respect to fouling stage and dry weight of fouling [3], [10]. In these projects, test patches were applied on ships' hulls, using a large variety of paints and coatings. They comprised epoxy-based hard coatings, silicone-based foul release coatings, and biocidal and non-biocidal self-polishing co-polymers (SPCs).

Three fouling stages were categorised as microfouling (e.g., biofilm, slime), macroflora (eg. filamentous algae), and macrofauna (eg. hard calcareous macrofouling). The fouling was removed by hand, scraping a surface of 10 x 75cm from the upper waterline downwards. Most vessels had a draught of 1 to 5m with minimal variation in depth of immersion. The draught of the ocean-going vessels varied between 6 and 12m.

The removed fouling was collected and stored for subsequent drying. The drying was carried out at 60°C until the weight remained constant. This procedure took 14 days in most cases. The dried sample was ceased glowing at 485°C to get the weight as ash-free dry weight. The samples of fouling were collected from test patches on vessels operating exclusively in the North Sea (N = 323) and worldwide (N = 40). The fouling present on the hull of the inspected ships developed over different periods of between three and 25 months.

Results

The evaluations of dry weight and ash dry weight on hard coatings are shown in Table 1 and Figure 1. Hard coatings displayed after exposure of at least six months showed macrofouling only; no dry weight could be measured for microfouling and macroflora. ›

Fouling stage	N (121)	Foul release coatings	
		Dry weight (g/m²) Arithmetic Mean (min - max)	Ash dry weight (g/m²) Arithmetic Mean (min - max)
Macrofauna	121	366 (10-2,298)	39 (3-59)

Table 3: Dry and ash dry weight in relation to fouling stage on hard coatings Source: LimnoMar

Vessel type	Mean wetted surface m²	microfouling kg	macroflora kg	macrofauna kg
Tanker	35,000	35	630	1,715
Bulker	23,000	23	414	1,127
Container ships	16,000	16	288	784
Cruise ship	27,000	27	486	1,323

Table 4: Dry weight of fouling from hulls of representative vessel types to be captured on failing antifouling paints Source: [12]

The mean dry weight of macrofauna resulted in 329 g/m² (min = 1, max = 2,298). It was evident that the fouling weight increased with each stage, but the variation increased as well. A similar pattern was evident when evaluating the dry weight on foul release coatings (Table 2 and figure 1). The mean weight of microfouling was 5 g/m² with variation from 1 to 25 g/m², the mean weight of macroflora was 34 with variation of 9 – 81, and of macrofauna with 199 and variation 1 – 2,221 g/m².

As expected, the fouling development and fouling dry weight on biocidal SPCs was reduced in relation to hard and foul release coatings (Table 3 and Figure 1). The mean dry weight was 1 g/ m² with no variation. Dry weight of macroflora resulted in a mean of 18 g/m² with an extreme variation of 1 – 105 g/m². An even higher variation was found on SPCs with macrofauna with a mean of 41 g/m² and a variation of 1 – 210 g/m².

Discussion

The evaluation of the dry weight of fouling also shows a strong relationship to the specific fouling stage on all substrates on foul release coatings and biocidal SPCs. These findings correspond well with investigations on the drag increasing from the microfouling to the macrofouling stage [4], [6] [11]. In addition, there are first indications that the variation in weight increases with fouling development [1]. The actual practice of cleaning failing antifouling paints presents challenges in capturing the removed fouling.

In Table 4, the dry weight of fouling per square metre is calculated for the wetted surface of representative types of vessels. It is evident that even on biocidal paints with low performance, very high mean weights can occur and are to be expected prior to cleaning. From those calculations it may be possible to estimate the amount of fouling which should be captured.

In most North Sea and Baltic ports, water visibility does not enable the scale of hull fouling to be checked by the optical methods which can be used in clear water [9]. In cases when the biofouling management records of the vessel provide insufficient data on the fouling type and coverage of the hull, samples from some representative areas of the hull can be collected and the amount of fouling which should be captured can be predicted.

In some ports such as Bremen, for example, high efficacy rates of capture are required [5]. By taking samples prior to cleaning, the port authority has a tool to survey the efficacy of capture. The estimation of the dry weight can deliver another chance for the control of high quality in-water cleaning.

The increasing weight of fouling from microfouling to macrofouling displays also demonstrates the benefits of cleaning at microfilm stage. It is easier and faster, and fouling can be achieved at a satisfactory level. Comparing the surfaces of biocidal antifouling paints, foul release and hard coatings, it is evident that hard coatings need to be cleaned at short intervals of approximately once every week or two weeks. Otherwise, the amount of fouling and the increasing adhesion force of fouling organisms will cause additional resistance, and efficient filtration and capture of fouled material will be harder to achieve.

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